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ANALYSIS OF COASTAL FRONT TORNADOES ASSOCIATED WITH TROPICAL STORM JOSEPHINE OVER EASTERN NORTH CAROLINA ON 8 OCTOBER 1996

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1. INTRODUCTION

During the morning hours of October 8, 1996, the remnants of Tropical Storm Josephine swept rapidly northeast across eastern North Carolina. The circulation produced by this system and the presence of a strong coastal thermal/moisture boundary (Vescio 1993) helped spawn three small, but relatively intense tornadoes. The injuries and property damage associated with the tornadoes were limited to isolated locations across the central North Carolina coastal counties.

The purpose of this study is to identify the mesoscale processes accompanying the event, to document the combination of factors that lead to tornadic development, and to show the effectiveness of WSR-88D data in detecting rapidly developing tropical severe weather environments. Hopefully a description of these factors and the accompanying WSR-88D information will aid forecasters in future similar situations.

2. SURFACE ANALYSIS

Only a small region was impacted by this short-lived event (Fig. 1). The short damage paths were confined to the central coastal locations from New Bern in Craven County, north to Aurora and Bath adjacent to the Pamlico River in Beaufort County. The most severe activity occurred between 1300 and 1430 UTC. The extent of damage ranged from destruction of several mobile homes, to downed power lines and uprooted trees as the tornadoes skipped across the two counties.

A surface analysis and streamline wind plot for 1200 UTC (Figs. 2 and 3) revealed a strong coastal warm front aligned southwest to northeast across the area. Southeast of the front, tropical air with temperatures around 25 ^{o}C (mid 70s ^{o}F) and dewpoints of 21-24 ^{o}C (70-75 ^{o}F) spiraled inland on strong southeast winds of 30-35 knots ahead of the Josephine circulation over northeast South Carolina. The strength of the coastal front was evident from the temperature differences across the boundary and by the pressure falls along the central North Carolina coast. Surface features and the streamline analysis at 1500 UTC (Figs. 4 and 5) showed the 992 mb low center moving northeast over the central coastal region shortly after the tornadoes touched down. Strong onshore southeast flow of 35 to 50 knots was evident over the coastal stretches on the east side of the low pressure and coastal front.

3. CONDITIONS ALOFT

The 1200 UTC sounding from Newport (MHX), North Carolina (Fig. 6) indicated a nearly saturated layer from the surface to 700 mb, with mid-level drying above. Based on the initial temperature and dewpoint, a CAPE (B+) of 677 J/Kg for a surface-based parcel was obtained. Most of the positive buoyancy was centered below 500 mb with little buoyancy observed above 400 mb. The 1200 UTC hodograph (Fig. 7) from MHX also indicated strong low level winds and directional shear below 700 mb, which was reflected in the 0-2 km storm relative helicity of 990 m^2/s^2.

Studies such as Johns et al. (1990) provide a conceptual model for the relationship between helicity and CAPE, and link this to the occurrence of tornado producing thunderstorms (Fig. 8). The very high helicity values for this event support the potential for damaging tornadoes even with relatively low CAPE values. Helicity values were greatly enhanced as the surface winds east of the front shifted from the east to the southeast and increased to over 35 knots, resulting in strong veering in the lowest 2 km.

To the west of the coastal front, the atmosphere was not conducive for severe weather, as revealed on the Greensboro (GSO), North Carolina 1200 UTC sounding (Fig. 9). The surface-based Lifted Index was +8 with the absence of CAPE for surface based parcels. The wind fields were not nearly as strong to the west of the front, and the 0-2 km storm relative helicity value at Greensboro was 88 m^2/s^2. The surface and upper air data suggested that the coastal front was important in regard to destablizing the atmosphere and increasing the low level helicity on its east side.

4. WSR-88D DATA

The WSR-88D Doppler Radar at Newport (KMHX) was vital in detecting the evolving conditions that eventually led to the tornado activity over eastern North Carolina. The Vertical Azimuth Display Wind Profile (VWP) at 0700 UTC (Fig. 10) showed conditions prior to the passage of the coastal front. Strong easterly flow at the lowest levels, with the winds veering sharply above 5000 feet, was indicative of the warm air advection aloft ahead of the westward advancing coastal front. By 0930 UTC, as the coastal front moved onshore, surface winds shifted to the southeast (Fig. 11). As the coastal front continued to move inland, and the remnants of Josephine approached from the southwest, the low-level winds rapidly increased to more than 50 knots. The increase in wind speed combined with the strong veering of winds at low levels (Fig. 12), set the stage for tornadic development in the vicinity of the boundary.

The 0.5 degree reflectivity from KMHX at 1247 UTC (Fig. 13) showed the enhanced convection lining up along the coastal boundary from Jacksonville north through New Bern to just east of Washington. At this time, the circulation associated with the remnants of Josephine apparently interacted with the coastal front, and induced strong rotation within the thunderstorms located just southwest of New Bern (Fig. 14). A severe thunderstorm warning based on the velocity signature was already in effect for eastern Jones and central Craven Counties. As the mesocyclone strengthened, the severe thunderstorm warning was upgraded to a tornado warning for central Craven County. By 1253 UTC, the velocity signature became better defined, with rotational values in excess of 45 knots, and the radar (Fig. 15) indicated a Tornado Vortex Signature (TVS).

An F1 tornado was observed just north of New Bern shortly after 1300 UTC, and tornado warnings were extended north into Beaufort County around 1315 UTC. Unfortunately, because of archive problems between 1305 and 1400 UTC due to the loss of power, additional 88D radar information is not available for this post event study as the storms passed out of Craven and into Beaufort County. However, additional mesocyclones were observed by the radar operator across central Beaufort County and produced two brief, but strong (F2), tornadoes along a path from near Aurora, across the Pamlico River to Bath, and to the east of Washington.

The mesocyclones that produced the tornadoes in this episode were generally smaller and weaker than those used to establish the Operational Support Facility (OSF) warning criteria. Although the tornado near New Bern had rotational velocities greater than 45 knots, the mesocyclone that produced the F2 tornado near Aurora had rotational velocities around 30 knots. The mesocyclones in this case were also quite shallow with rotational depths of less than 10,000 feet. This is similar to the study by Kuhl (1994) that showed some tornadoes across the eastern U.S. often develop from mesocyclones that are weaker than those examined by OSF. It is critical for NWS forecasters in the eastern region to closely monitor the storm relative velocity products when conditions are favorable for any rotation in convection, and be aware that tornadoes are possible from even weak mesocyclones.

5. CONCLUSION

The tornadic events that occurred over eastern North Carolina on October 8, 1996, most likely were a result of the interactions between a strong coastal front and the remnants of Tropical Storm Josephine. As the remnants of Josephine approached from the southwest, instability and helicity values to the east of the boundary were greatly enhanced. Low level winds shifted from the east to southeast, and increased from 25 knots to over 50 knots.

The WSR-88D provided high resolution data to define the location of the coastal front and several tornado producing mesocyclones. The VWP was able to detect the westward movement of the coastal front as low level winds shifted to the southeast and rapidly increased over the station. Several mesocyclones and one TVS were detected by the storm relative velocity products, enabling the NWS forecasters to issue timely and accurate tornado warnings.

ACKNOWLEDGMENTS

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REFERENCES

Johns, R. H., J. M. Davies, and P. W. Leftwich, 1990: An examination of the relationship of the 0-2km AGL "positive" wind shear to potential buoyant energy in strong and violent tornado situations. Preprints: *16th Conference on Severe Local Storms*, Kananaskis Park, Alberta, Amer. Meteor. Soc., 593-598.

Kuhl, S.K., 1994: A preliminary examination of the WSR-88D storm relative velocity map product for tornadic events within the Eastern Region of the National Weather Service. Postprints: *The First WSR-88D Users' Conference*, Norman, Oklahoma, WSR-88D Operational Support Facility, National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 339-350.

Vescio, M. D., K. K. Keeter, G. Dial, and P. Badgett, 1993: A low-top weak reflectivity severe weather episode along a thermal/moisture boundary in eastern North Carolina. Preprints: *17th Conference on Severe Local Storms*, St. Louis, Amer. Meteor. Soc., 628-632.

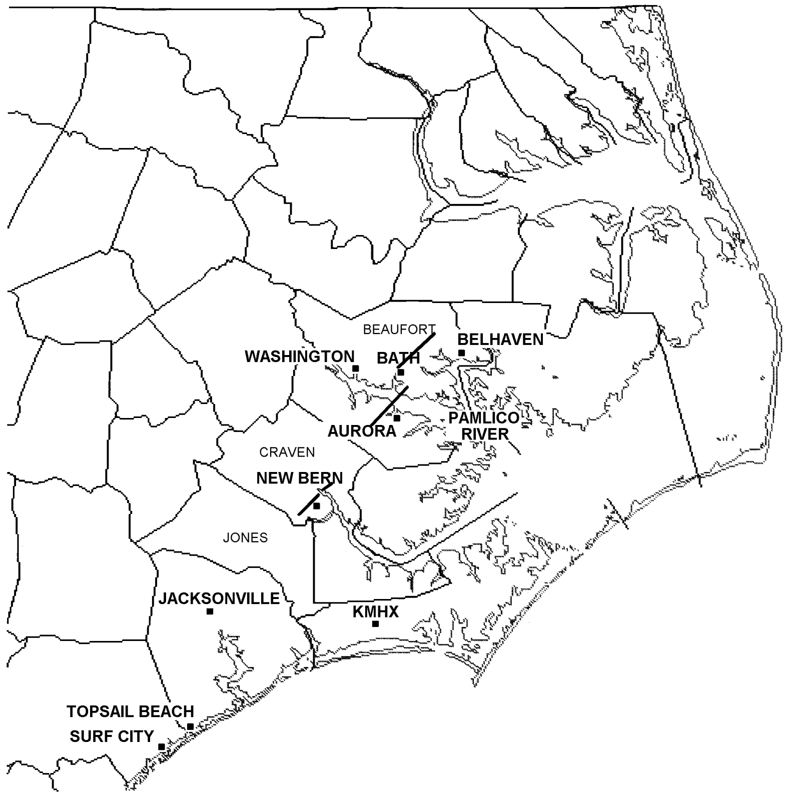

Figure 1. Map of eastern North Carolina. KMHX denote location of National Weather Service, Newport NC. Short lines indicate tornado paths.

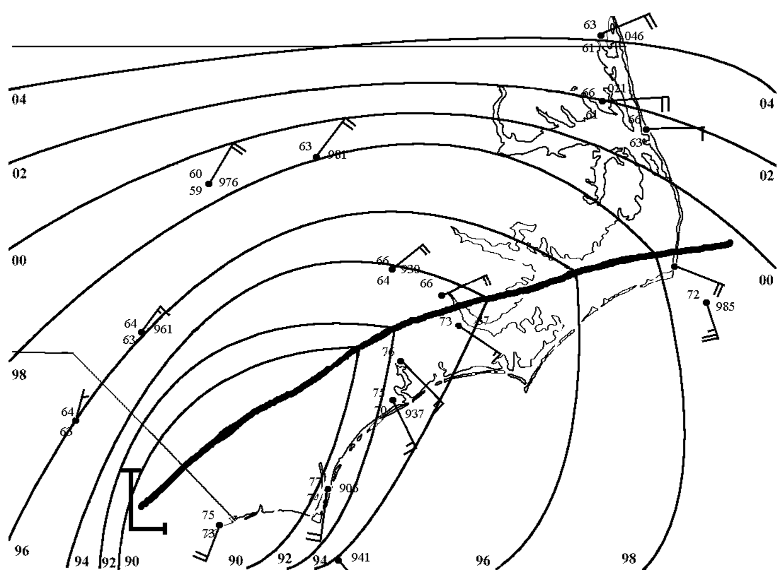

Figure 2. Surface analysis for 1200 UTC 8 October 1996. Contoured every 2 mb.

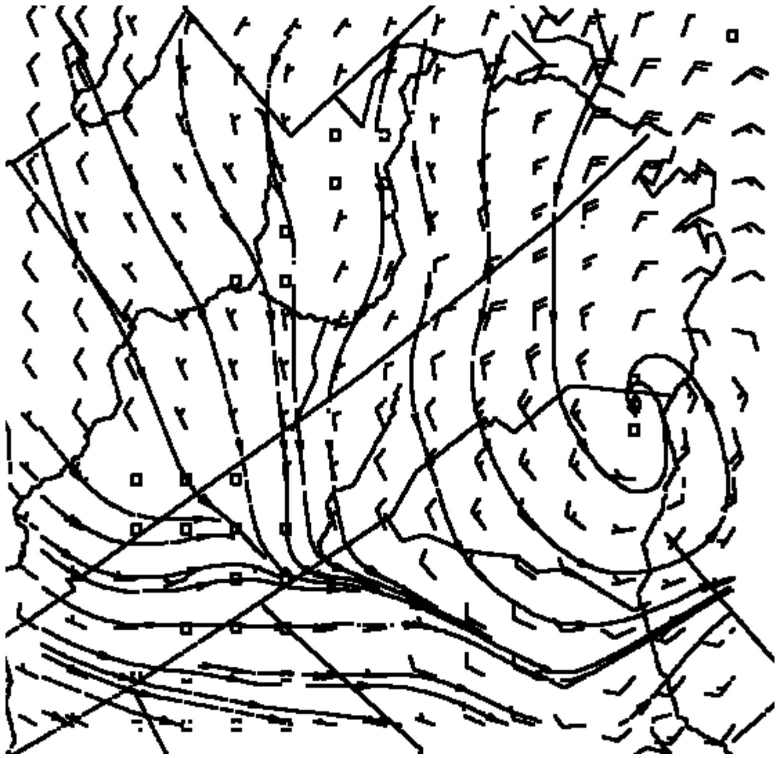

Figure 3. Streamline/wind plot from 1200 UTC 8 October 1996. (Note: wind barbs indicate wind direction and speed in knots; full barb denotes 10 knots; half barb denotes 5 knots).

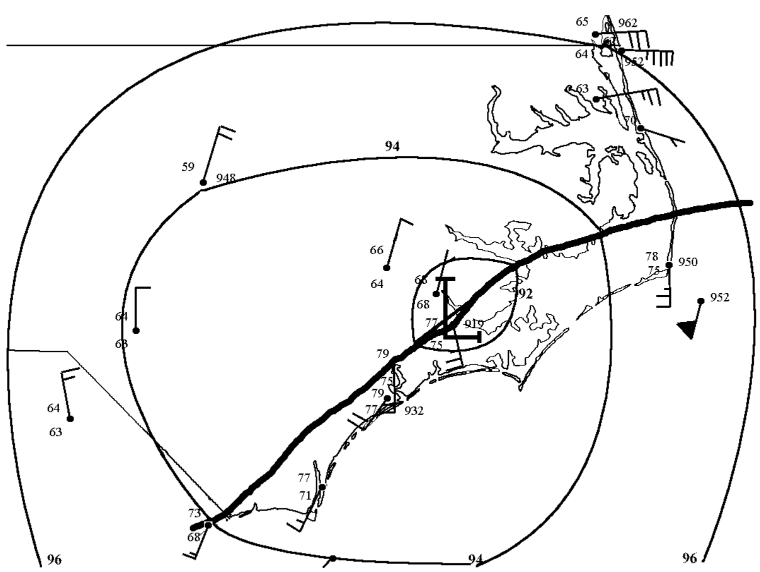

Figure 4. Surface analysis for 1500 UTC 8 October 1996. Contoured every 2 mb.

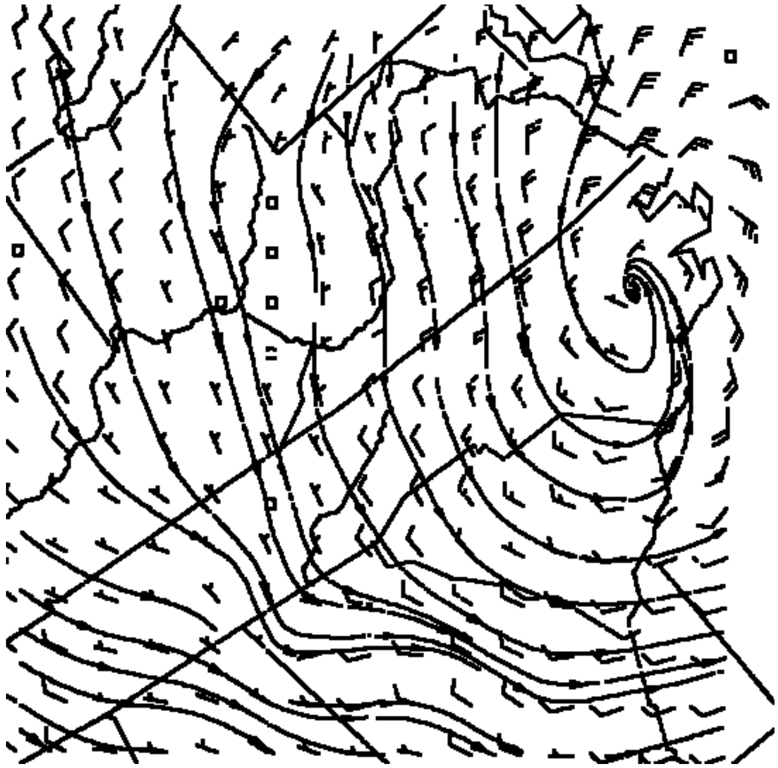

Figure 5. Streamline/wind plot from 1500 UTC 8 October 1996 (same convention for winds as in Fig. 3).

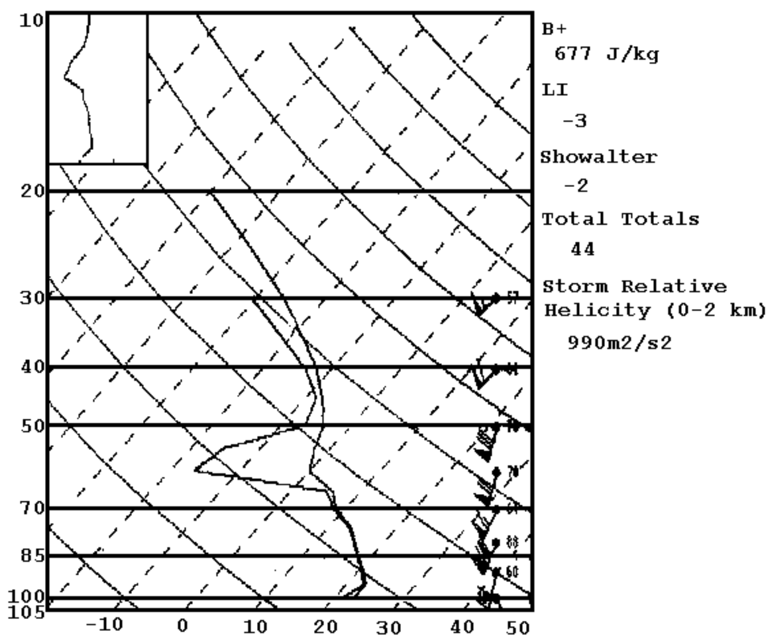

Figure 6. Sounding from 1200 UTC 8 October 1996 for Newport, North Carolina.

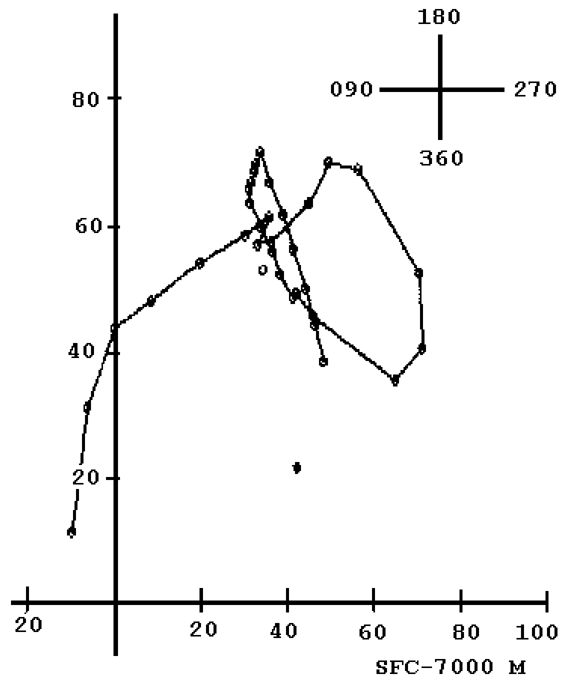

Figure 7. Hodograph from 1200 UTC 8 October 1996 for Newport, North Carolina.

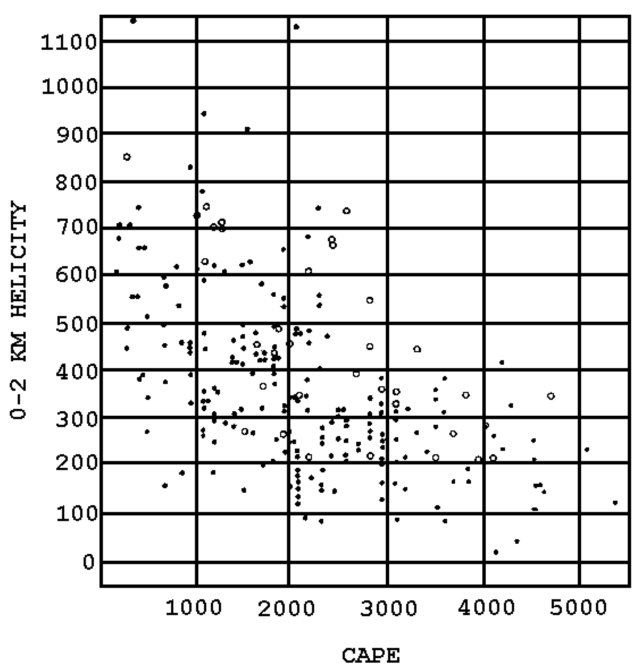

Figure 8. CAPE and 0-2 km helicity for 242 cases in data set from Johns et al. (1990). Open circles represent F4 & F5 intensity tornadoes.

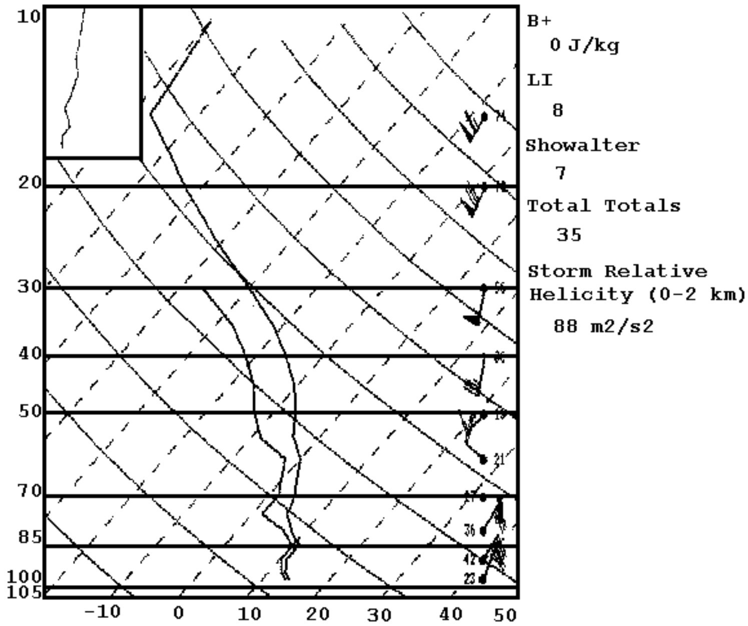

Figure 9. Sounding from 1200 UTC 8 October 1996 for Greensboro, North Carolina.

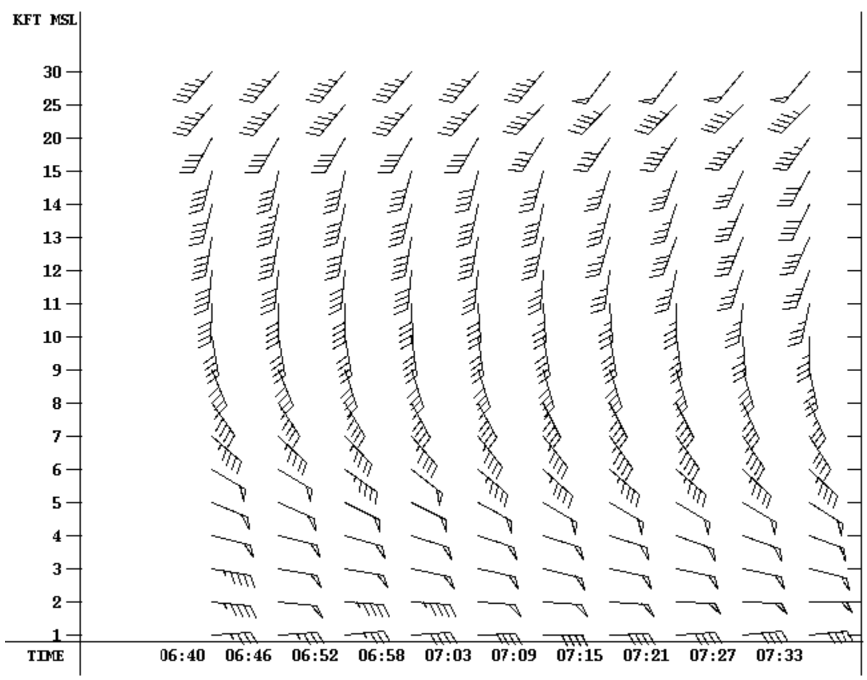

Figure 10. VAD wind profile from 0700 UTC 8 October 1996 for the KMHX WSR-88D.

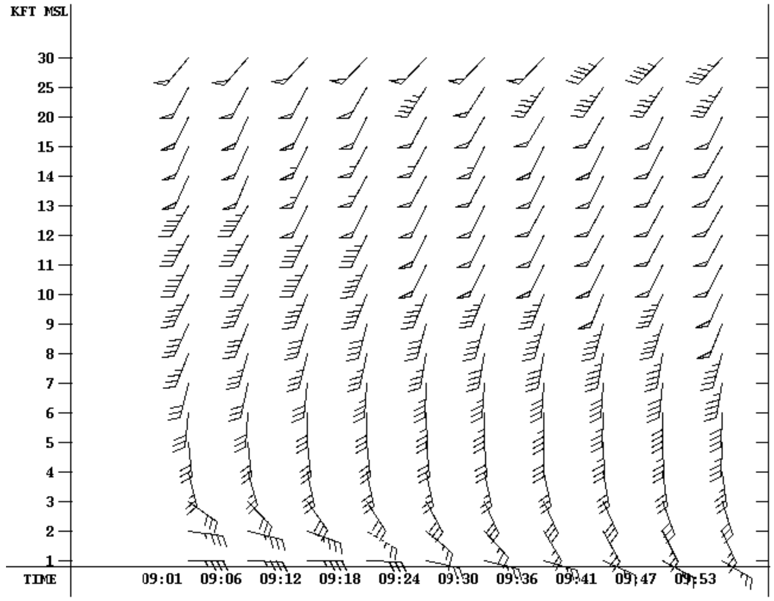

Figure 11. VAD wind profile from 0953 UTC 8 October 1996 for the KMHX WSR-88D.

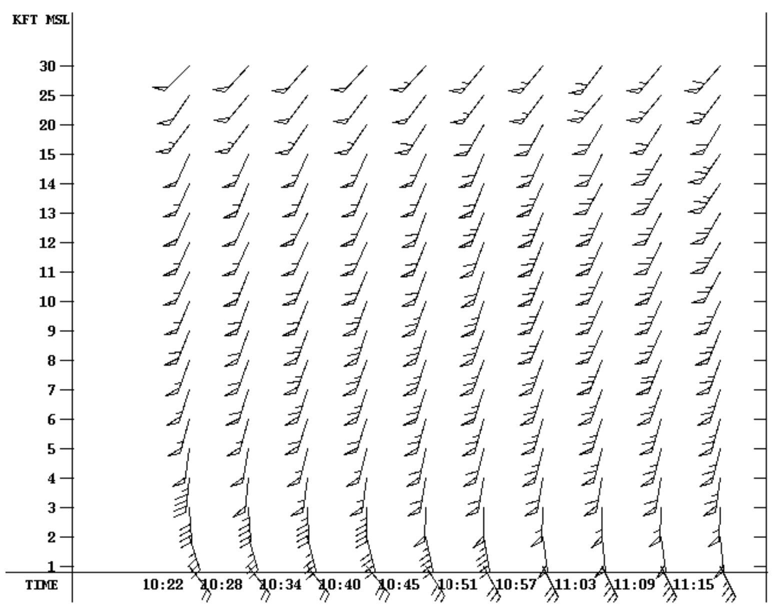

Figure 12. VAD wind profile from 1115 UTC 8 October 1996 for the KMHX WSR-88D.

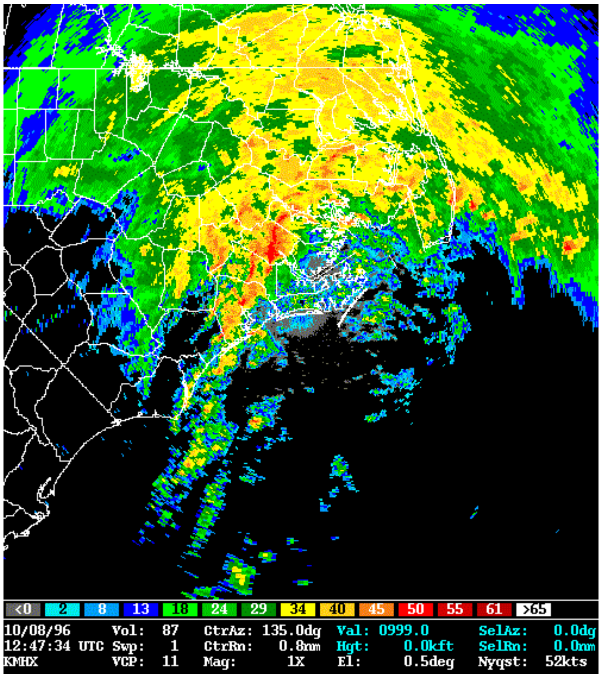

Figure 13. Base reflectiviy from 1247 UTC 8 October 1996 for the KMHX WSR-88D.

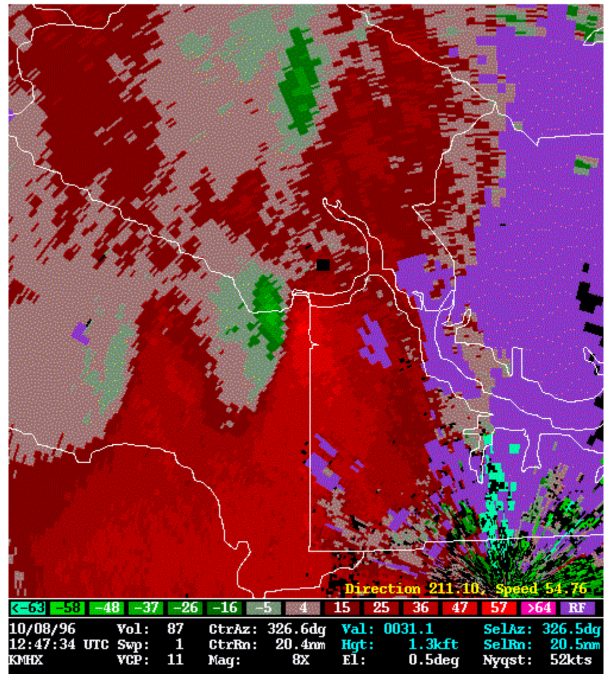

Figure 14. Storm relative velocity from 1247 UTC 8 October 1996 for the KMHX.

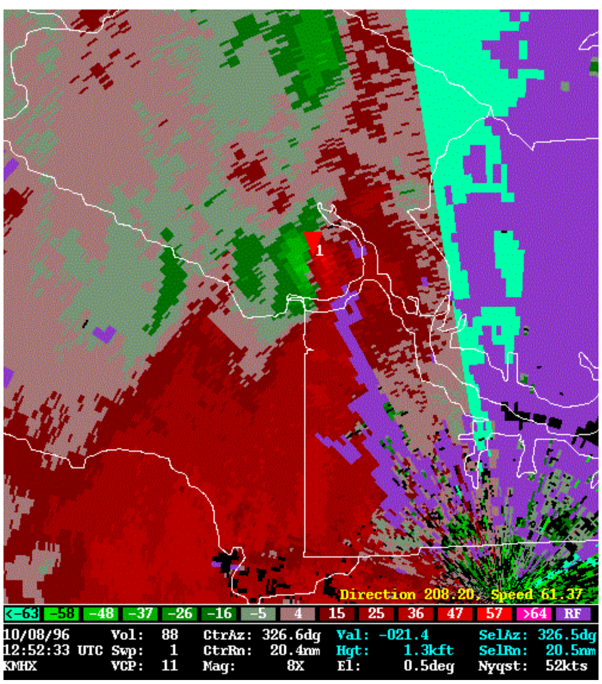

Figure 15. Storm relative velocity from 1252 UTC 8 October 1996 for the KMHX.